the statements made in the correspondents' replies. But we think that it will be admitted that as a whole those replies are eminently satisfactory.

A circumstance quite noteworthy, however, strikes the reader who scrutinises the lists as tabulated recording the instances of *injured*, and we would be glad to hear some explanation or interpretation of what at present seems inexplicable. Thus out of the first six races only three men are recorded as injured, while out of the next four races nine men are so recorded, five being mentioned in one race—that of 1845—and two more in the race of the following year. Again occurs a period of comparative immunity from injury, only one case being instanced in the next seven races. Once more is the order changed, for in the following four races four men are recorded as injured, while in the five remaining races of the series no injury whatever seems to have been sustained. The author does not seem to have instituted any inquiry on this point, yet surely it is one worth investigation, seeing that it is this very matter of liability to injury which is the sole subject of dispute, to settle which is the avowed object of his book. Was this injury-rate affected by the mode of training of the crews, the physical calibre or age of the individual men composing them, by the severity of the contest itself, or by the character of the season when the men trained and rowed?

ARCHIBALD MACLAREN

THOMSON & TAIT'S NATURAL PHILOSOPHY

Elements of Natural Philosophy. By Professors Sir W. Thomson and P. G. Tait. Clarendon Press Series. (Macmillan and Co., 1873.)

NATURAL Philosophy, which is the good old English name for what is now called Physical Science, has been long taught in two very different ways. One method is to begin by giving the student a thorough training in pure mathematics, so that when dynamical relations are afterwards presented to him in the form of mathematical equations, he at once appreciates the language, if not the ideas, of the new subject. The progress of science, according to this method, consists in bringing the different branches of science in succession under the power of the calculus. When this has been done for any particular science, it becomes in the estimation of the mathematician like an Alpine peak which has been scaled, retaining little to reward original explorers, though perhaps still of some use, as furnishing occupation to professional guides.

The other method of diffusing physical science is to render the senses familiar with physical phenomena, and the ear with the language of science, till the student becomes at length able both to perform and to describe experiments of his own. The investigator of this type is in no danger of having no more worlds to conquer, for he can always go back to his former measurements, and carry them forward to another place of decimals.

Each of these types of men of science is of service in the great work of subduing the earth to our use, but neither of them can fully accomplish the still greater work of strengthening their reason and developing new powers of thought. The pure mathematician endeavours to transfer the actual effort of thought from the natural phenomena to the symbols of his equations, and the pure experimentalist is apt to spend so much of his mental energy on matters of detail and calculation, that he has hardly any left for the higher forms of thought. Both of them are allowing themselves to acquire an unfruitful familiarity with the facts of nature, without taking advantage of the opportunity of awakening those powers of thought which each fresh revelation of nature is fitted to call forth.

There is, however, a third method of cultivating physical science, in which each department in turn is regarded, not merely as a collection of facts to be co-ordinated by means of the formulæ laid up in store by the pure mathematicians, but as itself a new mathesis by which new ideas may be developed.

Every science must have its fundamental ideas—modes of thought by which the process of our minds is brought into the most complete harmony with the process of nature—and these ideas have not attained their most perfect form as long as they are clothed with the imagery, not of the phenomena of the science itself, but of the machinery with which mathematicians have been accustomed to work problems about pure quantities.

Poinsôt has pointed out several of his dynamical investigations as instances of the advantage of keeping before the mind the things themselves rather than arbitrary symbols of them; and the mastery which Gauss displayed over every subject which he handled is, as he said himself, due to the fact that he never allowed himself to make a single step, without forming a distinct idea of the result of that step.

The book before us shows that the Professors of Natural Philosophy at Glasgow and Edinburgh have adopted this third method of diffusing physical science. It appears from their preface that it has been since 1863 a text-book in their classes, and that it is designed for use in schools and in the junior classes in Universities. The book is therefore primarily intended for students whose mathematical training has not been carried beyond the most elementary stage.

The matter of the book however bears but small resemblance to that of the treatises usually put into the hands of such students. We are very soon introduced to the combination of harmonic motions, to irratational strains, to Hamilton's characteristic function, &c., and in every case the reasoning is conducted by means of dynamical ideas, and not by making use of the analysis of pure quantity.

The student, if he has the opportunity of continuing his mathematical studies, may do so with greater relish when he is able to see in the mathematical equations the symbols of ideas which have been already presented to his mind in the more vivid colouring of dynamical phenomena. The differential calculus, for example, is at once recognised as the method of reasoning applicable to quantities in a state of continuous change. This is Newton's conception of Fluxions, and all attempts to banish the ideas of time and motion from the mind must fail, since continuity cannot be conceived by us except by following in imagination the course of a point which continues to exist while it moves in space.

The arrangement of the book differs from that which has hitherto been adopted in text-books. It has been

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usual to begin with those parts of the subject in which the idea of change, though implicitly involved in the very conception of force, is not explicitly developed so as to bring into view the different configurations successively assumed by the system. For this reason, the first place has generally been assigned to the doctrine of the equilibrium of forces and the equivalence of systems of forces. The science of pure statics, as thus set forth, is conversant with the relations of forces and of systems of forces to each other, and takes no account of the nature of the material systems to which they may be applied, or whether these systems are at rest or in motion. The concrete illustrations usually given relate to systems of forces in equilibrium, acting on bodies at rest, but the equilibrium of the forces is established by reasoning which has nothing to do with the nature of the body, or with its being at rest.

The practical reason for beginning with statics seems to be that the student is not supposed capable of following the changes of configuration which take place in moving systems. He is expected, however, to be able to follow trains of reasoning about forces, the idea of which can never be acquired apart from that of motion, and which can only be thought of apart from motion by a process of abstraction.

Profs. Thomson and Tait, on the contrary, begin with kinematics, the science of mere motion considered apart from the nature of the moving body and the causes which produce its motion. This science differs from geometry only by the explicit introduction of the idea of time as a measurable quantity. (The idea of time as a mere sequence of ideas is as necessary in geometry as in every other department of thought.) Hence kinematics, as involving the smallest number of fundamental ideas, has a metaphysical precedence over statics, which involves the idea of force, which in its turn implies the idea of matter as well as that of motion.

In kinematics, the conception of displacement comes before that of velocity, which is the rate of displacement. And here we cannot but regret that the authors, one of whom at least is an ardent disciple of Hamilton, have not at once pointed out that every displacement is a vector, and taken the opportunity of explaining the addition of vectors as a process, which, applied primarily to displacements, is equally applicable to velocities, or the rates of change of displacement, and to accelerations, or the rates of change of velocities. For it is only in this way that the method of Newton, to which we are glad to see that our authors have reverted, can be fully understood, and the "parallelogram of forces" deduced from the "parallelogram of velocities." Another conception of Hamilton's, however, that of the hodograph, is early introduced and employed with great effect. The fundamental idea of the hodograph is the same as that of vectors in general. The velocity of a body, being a vector, is defined by its magnitude and direction, so that velocities may be represented by straight lines, and these straight lines may be moved parallel to themselves into whatever position is most suitable for exhibiting their geometrical relations, as for instance in the hodograph they are all drawn from one point. The same idea is made use of in the theorems of the "triangle" and the "polygon" of forces, and in the more general method of "diagrams of stress," in which the lines which represent the stresses are drawn, not in the positions in which they actually exist, but in those positions which most fully exhibit their geometrical relations. We are sorry that a certain amount of slight is thrown on these methods in § 411, where a different proposition is called the *true* triangle of forces.

It is when a writer proceeds to set forth the first principle of dynamics that his true character as a sound thinker or otherwise becomes conspicuous. And here we are glad to see that the authors follow Newton, whose Leges Motûs, more perhaps than any other part of his great work, exhibit the unimproveable completeness of that mind without a flaw.

We would particularly recommend to writers on philosophy, first to deduce from the best philosophical data at their command a definition of equal intervals of time, and then to turn to § 212, where such a definition is given as a logical conversion of Newton's First Law.

But it is in the exposition of the Third Law, which affirms that the actions between bodies are mutual, that our authors have brought to light a doctrine, which, though clearly stated by Newton, remained unknown to generations of students and commentators, and even when acknowledged by the whole scientific world was not known to be contained in a paragraph of the *Principia* till it was pointed out by our authors in an article on "Energy" in *Good Words*, October 1862.

Our limits forbid us from following the authors as they carry the student through the theories of varying action, kinetic force, electric images, and elastic solids. We can only express our sympathy with the efforts of men, thoroughly conversant with all that mathematicians have achieved, to divest scientific truths of that symbolic language in which the mathematicians have left them, and to clothe them in words, developed by legitimate methods from our mother tongue, but rendered precise by clear definitions, and familiar by well-rounded statements.

Mathematicians may flatter themselves that they possess new ideas which mere human language is as yet unable to express. Let them make the effort to express these ideas in appropriate words without the aid of symbols, and if they succeed they will not only lay us laymen under a lasting obligation, but, we venture to say, they will find themselves very much enlightened during the process, and will even be doubtful whether the ideas as expressed in symbols had ever quite found their way out of the equations into their minds.

TYNDALL'S FORMS OF WATER

The Forms of Water in Clouds and Rivers, Ice, and Glaciers. By John Tyndall, LL.D., F.R.S. (London: H. S. King & Co.)

WHATEVER comes from Dr. Tyndall's pen is sure to be vivid and clear. The present little volume forms no exception to this rule. It seems to have been composed partly in the form of popular lectures and partly as a sort of journal of a visit last year to the author's favourite holiday haunts among the Swiss glaciers. Very readable, it nevertheless betrays this composite origin, and wears more the aspect of a piece of book-making than

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